

## GRAPHENE AS ELECTRODE MATERIAL FOR THE GREATER POWER GENERATION IN MICROBIAL FUEL CELL

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### ABSTRACT

*The future of energy will dependent majorly on renewable sources; Microbial fuel cell (MFC) technology is a recent and a powerful technology which uses energy present in wastewater to convert into electrical energy with the help of microorganisms. The performance of MFC directly depends on the kinetics of the electrode reactions within the fuel cell, however, the overall low power density of the MFC and the high cost of its components are two major barriers for its commercialization. This barrier can be overcome by increasing surface area which is possible by using graphene based electrode and higher electro catalytic activity compared to the conventional carbon materials. In this work, Graphene oxide was synthesized by using the modified Hummers method and the synthesized nano particles were characterized by the XRD, SEM, FTIR. Further, these nano particles are coated on carbon electrodes to improve the power density and max achieved is  $98 \text{ m W/m}^2$ , whereas it found only  $9 \text{ m W/m}^2$  without nano particles coating on carbon electrodes. There is a massive 90 % the difference in power density.*

**KEY WORDS:** Microbial Fuel Cell, Electrode, Graphene & Power Density

Original Article

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### INTRODUCTION

Microbial fuel cells (MFCs) are receiving great attention because they produce renewable bio energy (electricity) from organic matters which is sustainable in nature and also treats wastewater to a great extent. The efficiency of MFCs depends on anode electrode capacity to transfer the electrons, substrate material, proton exchange membrane capacity, catalyst, internal resistance, electrode spacing, cathode electrodes, microorganisms present in wastewater and their life [1-2]. These limitations addressed partially with the graphene-modified materials. Some of the limitations are taken care of by using a series of design concepts for MFC. In spite of many challenges, graphene-modified electrodes are proved as promising for MFC development and decreased BOD levels inorganic waste by converting it into electrical energy[3]. Currently, the function materials and their applications have attracted the most attention due to their outstanding properties concerning the bio electro catalytic degradation of organic molecules in organic wastes [4]

### Graphene

Electronic properties of Graphene is one of the most useful properties, it has high electrical and is among the strongest substances known. A single carbon layer of the graphitic structure can be considered as the final member and the term graphene is used to designate the individual carbon layers in graphite. It is a single carbon layer of the graphite structure and the term graphene is used only when the reactions, structural relations or other properties of individual layers are discussed.

## Graphene Oxide

When strong oxidizing agents are used to oxidize graphite, oxygenated functionalities are introduced in the structure of the graphite, which makes the material hydrophilic, and also expands the layer separation[5].

The number of layers is the major difference between grapheme oxide and graphite oxide. Although graphite oxide is a multilayer system, monolayer flakes and few-layer flakes can be found in grapheme oxide.

## MATERIALS AND METHODS

### Various Methods for Producing Nano Particles or Grapheme Oxide from Graphite

The most common way to produce grapheme derivatives like grapheme oxide is via the chemical oxidation of graphite to graphite oxide followed by subsequent exfoliation to grapheme oxide. Graphite oxide is typically synthesized by either the method of Brodie, Staudenmaier, or Hummers, or by a variation of these methods. All three synthesis routes resulting in the oxidation of graphite to various levels[6]. In the cases of Boride's and Staudenmaier's methods a combination of potassium chlorate ( $\text{KClO}_3$ ) with nitric acid ( $\text{HNO}_3$ ), Boride, or sulfuric acid ( $\text{H}_2\text{SO}_4$ ), Staudenmaier, are used to oxidize the graphite. In contrast, the Hummers method involves the treatment of graphite with potassium permanganate ( $\text{KMnO}_4$ ) and sulfuric acid ( $\text{H}_2\text{SO}_4$ ). It was shown that the purest graphite oxide is synthesized with Boride's method, although it is also the most time-consuming method. Nevertheless, in the cases of Staudenmaiers or Hummers approach there is a trade of between time advantage and possible contaminations due to sulfur and excess permanganate ions.

### Production of Grapheme Oxide (GO) Nano-Particles by Hummer Method

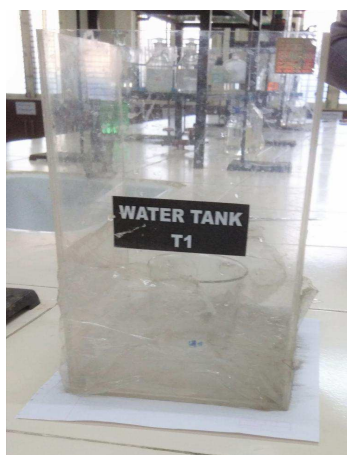
Grapheme oxide was synthesized by the Hummers method through oxidation of graphite.

The chemicals required for this process are

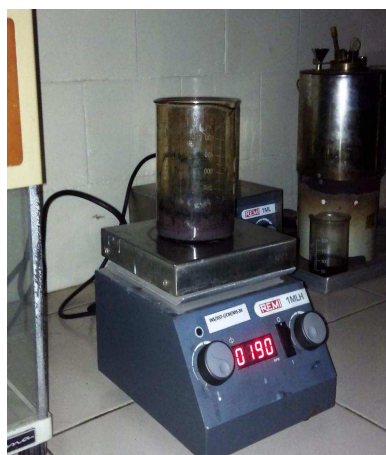
Graphite Flakes, Sodiumnitrate, Potassium permanganate, Hydrogen peroxide Sulphuric acid, Hydrochloric acid.

The stepwise preparation is given as follows[7]

- Equal amounts of Graphite flakes and sodium nitrate ( $\text{NaNO}_3$ ) i.e 2 gms each were mixed in 50 ml of high concentrated Sulphuric acid ( $\text{H}_2\text{SO}_4$ ) in a flask, the solution is mixed continuously and to maintain temperature ice bath is used ( $0 - 5^\circ\text{C}$ )



**Figure 1: Ice Bath**



**Figure 2: Magnetic Stirring**

- After 2 hours of potassium permanganate (6 g) was added very slowly to the suspension as shown in figure 2. The rate of addition was carefully controlled to keep the reaction temperature lower than 15°C.
- The ice bath was then removed, and the mixture was stirred at 35°C until it became pasty brownish and kept under stirring for 2 days.
- It is then diluted with slow addition of 100 ml water. The reaction temperature was rapidly increased to 98°C with effervescence, and the color changed to brown color, clearly seen in figure 3



**Figure 3: Continuous Stirring While Adding Water**

- Further, this solution was diluted by adding an additional 200 ml of water stirred continuously.
- The solution is finally treated with 10 ml H<sub>2</sub>O<sub>2</sub> to terminate the reaction by the appearance of yellow color.
- For purification, the mixture was kept for centrifugation with 10% HCl as shown in figure 4



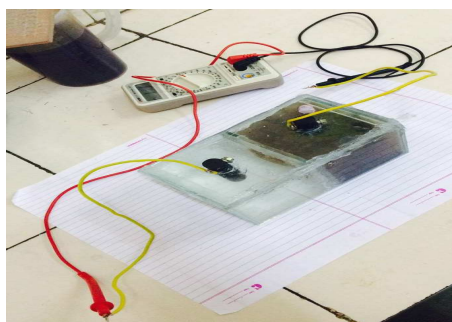
**Figure 4: Centrifugation of Solution**

- After filtration and drying at room temperature, the graphene oxide (GO) was obtained as a powder.

The synthesized GO by Hummer's methods is characterized by X-Ray Diffraction Analysis (XRD), Fourier Transform- Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM)

### Construction of Microbial Fuel Cell

1.5 L volume containing fuel cell is set up by placing both electrodes inside the fuel cell tightly in respective compartments. Construction of Microbial Fuel Cell consists of one anode and cathode compartment each of 9 x 9 cm. In-between the compartments lie Nafion i.e. a Proton Exchange Membrane which allows faster transmission of electrons. Anode compartment is sealed air-tight whereas cathodic compartment is kept open for air sparking. Waste material such as sewage wastewater is used as feed and will be kept in the anodic compartment whereas the cathodic compartment contains a salt of pH 7



**Figure 5: Microbial Fuel Cell Setup**

## RESULTS AND DISCUSSIONS

Performance of MFC is observed using voltage and current readings till day six, as it was decreasing after day five. After keen observation of voltage and current power, density was calculated. It is found that with graphene electrodes power density is very high comparative with other carbon electrodes. Maximum power density achieved is  $98 \text{ m W/m}^2$  as shown in table 1

**Table 1: Observation Table of Microbial Fuel Cell**

	Time hr	Voltage(V) mV	Current(I) mA	Power(P) W ( $\times 10^{-6}$ )	Power Density(PD) mW/m <sup>2</sup>	pH
Day1	0	0	0	0	0	6.9
Day 2	18	300	0.14	42	5.185185185	6.9
	19.5	330	0.14	46.2	5.703703704	6.9
	20	308	0.16	49.28	6.083950617	6.9
	20.5	320.2	0.18	57.636	7.115555556	6.9
	21	328.8	0.18	59.184	7.306666667	6.9
	21.5	319.6	0.2	63.92	7.891358025	6.9
	22	334	0.22	73.48	9.071604938	6.9
	22.5	360.2	0.22	79.244	9.783209877	6.9
	23	373	0.22	82.06	10.1308642	6.9
	23.5	380.2	0.22	83.644	10.32641975	6.9
	24.5	390.6	0.22	85.932	10.60888889	6.9
Day 3	42	592	0.32	189.44	23.38765432	6.9
	43	614	0.36	221.04	27.28888889	6.9
	44.5	646	0.38	245.48	30.30617284	6.9
	46	660	0.46	303.6	37.48148148	6.9
	46.5	634	0.5	317	39.13580247	6.9
	47.5	676	0.52	351.52	43.39753086	6.9
Day 4	67.5	950	0.72	684	84.44444444	6.9
	70	960	0.72	691.2	85.33333333	6.9
	72.5	950	0.72	684	84.44444444	6.9
Day 5	92	994	0.78	775.32	95.71851852	6.9
	93.5	974	0.82	798.68	98.60246914	6.9
Day 6	105.5	948	0.71	673	84.125	6.9

In the preliminary experiments, cheap copper electrodes were used for anode and cathode chamber. The efficiency obtained here is about 46%. In order to achieve better efficiencies construction of MFC is changed and copper electrodes are replaced with graphite electrodes for their good ability of bio film formation.

Proper enhancement can be done by coating Nano materials and thereby increasing  $e^-$  transfer and hence electricity generation. The better replacement for this is the carbon-based electrode. GO has sixty -times better conductivity, higher stability, greater sensitivity and also more surface charge density compared to other materials such as carbon nanotubes (CNTs). Carbon electrodes are coated with GO nano particles and the same wastewater and operating conditions are maintained. The power density is improved to 98 mW/m<sup>2</sup>

## CONCLUSIONS

MFC can be used for power generation in a safe and sustainable manner. The generation of renewable energy from wastewater has been demonstrated using a simple batch Microbial Fuel Cell with khan river water. The grapheme oxide powder that is formed with the help of hummer's method is effectively used for plating of carbon electrodes. These electrodes are then ultimately used for generation of electricity. Grapheme is an emerging material with very good electrical, physical and chemical properties, in the development of microbial fuel cells (MFC), it is playing a very important role. Due to the, higher specific surface area, good electrical conductivity and more active microbe-electrode-electrolyte interaction grapheme-based anodes proved their efficiency. Increased active sites and conductivity helped cathodes in the oxygen reduction reaction. Despite many challenges like a synthesis of graphene oxide, a coating on

electrodes this technology proved as promising for developing MFCs to achieve sustainable water/wastewater treatment and bio energy production.

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